APD Module Requirements

08-Mar-06

Version 1.0

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1 Introduction

1.1 Purpose

The purpose of this document is to define the APD Module for the NOvA Experiment and to present the requirements of its operation. The document is numbered in outline format, with *level-3 outline numbers corresponding to specific requirements or specifications.*

1.2 Scope

This document will present the requirements but will not specify how those requirements are to be met. In this sense, it is not a description of the intended implementation.

1.3 Rationale

To meet the requirements of the NOvA Experiment for the read out of the photonic signal from the liquid scintillator detector modules, Avalanche Photodiode (APD) arrays have been selected as an optimal device in terms of detection capability and cost. Because of the limited number of photons produced and transported along the length of the liquid scintillator cells via wavelength-shifting optical fibers, the APD's must be operated in a way that maximizes signal detection efficiency while minimizing noise. The requirements for low-noise front-end electronics are presented in the document "Front End Electronics Requirements". In the present document, the requirements on the mechanical housing for the APD arrays and associated systems required to operate the APD's are enumerated. This includes the requirements on the (1) structural, (2) thermal, (3) environmental, (4) optical and (5) electrical couplings/interfaces that must be provided by the APD module system.

1.4 Terminology

Acronym/Name	Description
APD Array	32-channel avalanche photodiode array
APD Board	Carrier PC Board for the APD array
FEB	Front End (Electronics) Board
DAQ	Data Acquisition System
TEC	Thermoelectric (Peltier Effect) Cooler
HV	High Voltage for APD bias in range ~ 350V – 450V
Detector Module	32-cell liquid scintillator-filled PVC extrusion
WLS fiber	Wavelength-shifting optical fiber
Cookie	WLS fiber-end housing onto which the APD module plugs
Manifold	Portion of detector module that routes fibers to the cookie

1.5 Detector information

Parameter	Value
Number of APD Modules	23,808
Number of APD pixels	761,856

2 Overview

The scintillator detector module consists of a TiO_2-loaded PVC extrusion that forms 32 container cells for liquid scintillator. Into each cell is installed a single looped wavelength-shifting fiber that transmits the optical signal through both ends to a manifold at the end of the module, along with the fiber ends from other cells. Thus there is one 32-channel APD module per scintillator detector module. The 64 fiber ends from one detector module are interfaced to the active surface of the 32 APD pixels in the APD array, with two fiber ends illuminating each pixel.

The APD module provides an optical interface between a single 32-cell scintillator detector module and a 32-channel Avalanche Photodiode array, which is used to convert the optical signals from the detector module to electronic signals. The APD module thus also provides an interface to the Front End Board (FEB).

In addition to the interfaces mentioned above the APD module must provide the means to operate the APD array in a robust and problem-free manner. A stable bias voltage must be supplied. Control and readback of APD array temperature must be provided. Exposure to light and moisture must be avoided during operation of the APD module. Ease of assembly and disassembly must be considered.

Consequently, the APD module is currently consists of the following components: (a) a 32-channel APD array, (b) a "carrier" printed circuit board on which the APD array is mounted, (c) a thermoelectric cooler (TEC) chip, (d) a heat sink for removal of heat from the TEC, and (e) an enclosure ("clam shell").

3 Requirements

3.1 Avalanche Photodiode Array

Avalanche photodiode technology has been selected for the baseline optical signal read out for NOvA, on the basis of cost and reliability. The requirements presented here assume that the experiment will employ one 32-channel APD array per scintillator detector module. The APD arrays will be mounted by the supplier to the carrier board via 'flip-chip' bump bonding.

3.2 Carrier Board and Mounting of APD Array

The carrier board provides structural support for the APD array as well as the electrical connection to the FEB. It also serves as an alignment jig for the array.

3.2.1 The carrier board will alignthe fibers to the APD array.

3.3 Optical Coupling: Cookie/APD Interface

The APD Module will be affixed to the manifold of the corresponding scintillator module. The portion of the manifold that holds the fiber ends and attaches to the APD Module is referred to as the cookie.

3.3.1 The APD Module rigidly mounts to the cookie/manifold assembly.

This is to ensure stable positioning of the fibers terminating at the cookie surface with respect to the APD pixels, and avoid damage to the APD by contact with the cookie.

3.4 Electrical Connection to the Front-End Board

3.4.1 The carrier board must carry signal and temperature sensor lines from the APD array to the FEB

3.4.2 The carrier board must carry the APD bias voltage and cooling controller signal lines from the FEB to the APD array/TE cooler.

3.5 Cooling of the APD Array

3.5.1 The APD module must allow temperature control of the APD array.

3.5.2 The APD module must allow disassembly for ease of replacement of a failing TEC.

Since the APD arrays are cost-drivers for the readout system, it is important to design a system that does not require many spare units. Making the TEC swappable will allow reuse of APD arrays interfaced with TEC's that fail.

3.5.3 The APD modulewill remove heat from the hot side of the TEC.

3.5.4 The TEC plus heat sink assembly must not apply significant mechanical stress to the APD Array.

To achieve most effective cooling of the array, the TEC/heat sink assembly must make good thermal contact with the array. This must be accomplished without stressing the APD array.

3.5.5 The temperature of the APD will be monitored.

Both gain and thermal APD noise depends on temperature. Consequently the APD module must include a device to measure the APD array temperature.

3.6 Environmental Conditions for the APD Array

The APD Module enclosure must be designed so as to satisfy several requirements on the environmental conditions for the APD array.

3.6.1 The enclosure should isolate the APD from ambient light.

APD's are photosensitive devices. Light leaks will contribute to the noise level.

3.6.2 The humidity inside the enclosure should be low enough to prevent condensation on the APD array.

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